TESTING AND CONFORMANCE FRAMEWORK DEVELOPMENT GUIDE

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Executive Summary

This document is a development guide for creating a comprehensive framework and action plan for a smart grid standards testing, conformity and certification ecosystem. The SGIP Testing and Certification Committee (SGTCC) is charged with the development of the final framework and action plan. This document provides high level guidance, core principles, and desired outcomes that the framework is expected to follow and achieve.

A mature smart grid standards ecosystem has a multitude of key actors that must interact to achieve the long term goal of pervasive interoperable systems in the smart grid and include:

- Standards Organizations
- Hardware and Software Vendors
- Test Labs
- Purchasers and Users of Smart Grid Products and Services
- Federal, State, and Local Government and Regulatory Agencies and Legislatures

This guide describes the roles and responsibilities of these key actors, defines key terms and definitions to facilitate clear understanding of the problem at hand, describes major workflows, describes usage scenarios for the desired framework, and provides examples of these elements.

There are few comparable activities in other industries to draw from given the unique place electric power infrastructure has in society and in the support of other critical infrastructure. One relevant example is the transformations in telecommunication carrier networks in the past decade moving from legacy, circuit-switched copper networks to IP oriented fiber optic networks. This is an example that shares some fundamental similarities to transformation of energy networks and can help facilitate understanding of the goals to be achieved and value to be obtained in developing a framework for the smart grid.

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1 Background and Intended Audience

This section provides a brief background on Smart Grid testing and certification, the purpose of this document and describes its intended audience.

Testing and certification activities for smart grid devices and systems are an essential element necessary to assure smart grid interoperability. Conformance and interoperability assessments rely on standards and standardized test methods and processes to assure consistent application and repeatability of testing programs used for verification.

This purpose of this document is to provide a guiding framework for the development of a final framework and action plan to implement a smart grid standards testing and conformity ecosystem. The Smart Grid Interoperability Panel's Testing and Certification Committee (SGTCC) is charged with the development of the final framework and action plan. The objective of this framework is to ensure seamless interoperability between the components of the Smart Grid. This document provides high level guidance, core principles, and desired outcomes that the final framework and action plan is expected to follow and achieve.

While primary audiences for this document are the SGTCC and related committees supporting smart grid interoperability efforts, the document will also provide value to other industry stakeholders that play a vital role in assuring an interoperable smart grid.

1.1 Background

Under the Energy Independence and Security Act (EISA) of 2007, the National Institute of Standards and Technology (NIST) has *"primary responsibility to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems."* In April 2009, NIST launched a three-phase plan to expedite development and promote widespread adoption of Smart Grid interoperability standards. The third phase of this plan specifically addresses testing and certification and is summarized below:

Develop and implement a framework for testing and certification. *Testing and certification of how standards are implemented in Smart Grid devices, systems, and processes are essential to ensure interoperability and security under realistic operating conditions. Industry has indicated that this is a high priority. NIST, in consultation with industry, government, and other stakeholders, will propose to develop an overall plan for a testing and certification framework and initiate steps toward implementation. ..*[1]

The Smart Grid Interoperability Panel (SGIP) was created by NIST in November 2009 as a public-private partnership to support further standards development that will be needed to address gaps, harmonize standards, and incorporate evolving technology. The SGIP established the Smart Grid Testing and Certification Committee as a standing committee chartered to develop the final framework and action plan for Smart Grid testing and certification.

1.2 *Intended Audience*

It is expected that this document will primarily serve to provide guidance to the SGTCC in the development and implementation of a Smart Grid Testing and Certification final framework and action plan. The SGTCC will be comprised of experts in the field of testing and certification with backgrounds in a variety of technology areas including power engineering, communications, wireless technologies, software interoperability testing, and protection and safety engineering.

The testing and conformity ecosystem goes beyond specific testing and technical expertise, and includes many stakeholder entities that will have a role in achieving Smart Grid interoperability. These include regulators, end users and manufacturers of systems and devices, participating contributors to SGIP committees related to testing (e.g. architecture, cyber-security), standards organizations, laboratories and accreditors.

1.2.1 *Legislators and Regulators*

This document will be used by NIST staff to describe the value proposition for testing and conformance to legislators, regulators, and other high-ranking officials and decision makers. A robust and effective testing and certification system requires a “demand driver” to gain the broad acceptance and adoption by industry that will advance system interoperability. Demand may be driven by end user market forces or may be driven by regulatory enforcement.

This document will provide high level guidance to the SGTCC on required elements of the Smart Grid testing and certification final framework and action plan. As the key committee chartered to develop the framework, the SGTCC will be the principle beneficiary of this document. The SGTCC will require a high degree of interaction with other SGIP committees in the execution of its work, thus this document also serves as a valuable reference tool for the Smart Grid Architecture Committee (SGAC) and the Cyber Security Working Group (CSWG). Additionally, Domain Expert Working Groups and Priority Action Plan

[1] Excerpted from the NIST website: http://www.nist.gov/smartgrid/index.cfm

committees may also benefit from a basic understanding on testing and certification, as well as proposed output of the SGTCC, to help align with their respective efforts as necessary.

1.2.2 *SGIP Stakeholders*

SGIP stakeholders in testing and certification are a broad group including end users and operators of Smart Grid systems and devices, manufacturers of those systems and devices, standards setting organizations, test laboratories, accreditors and other constituencies represented within the many SGIP stakeholder categories.

Many of these stakeholders have a solid understanding of testing, conformity and certification, and the role their organizations play in the process. For some, the basic terminologies and practices used in the testing and certification process are less familiar, thus this document also provides some basic information that can be used to familiarize a non-technical audience with testing and conformity and its role in enabling interoperability.

2 Scope, Rationale, and Need

This section introduces key concepts employed throughout this document in addition to describing the problem for which the conformity assessment framework is a proposed solution.

2.1 *Framework Goals*

The essential goal of the final framework and action plan is to present a comprehensive approach to close the Conformity Assessment gaps uncovered in the "Existing Conformity Assessment Program Landscape"[2] and accelerate the development and implementation of industry programs that enable Smart Grid interoperability.

A framework can be defined as a basic conceptual structure used to solve a complex issue; alternatively as a set of processes, concepts, best practices, examples and tools. More specific to Smart Grid testing and certification, the framework provides the suite of requirements and rules that the key actors must implement in order to achieve interoperability.

The SGTCC will have the primary responsibility for constructing the final framework as well as the action plans for development of documentation and associated artifacts supporting testing and certification programs that support Smart Grid interoperability. The framework shall provide a guide on how to coordinate multiple testing and certification programs across the Smart Grid ecosystem to ensure products based on Smart Grid standards provide end to end interoperability throughout the grid.

The framework must help ensure a consistent level of testing for products based on the same Smart Grid standards, as well as ensuring consistency in the implementation of test programs among different

[2] Existing Conformity Assessment Program Landscape, EnerNex Corporation, 2009

standards. The framework must address the depth of testing to be executed within individual standards or across multiple standards depending on the technology issues being addressed and the testing requirements defined within the Smart Grid ecosystem. Seamless interoperability is a desired outcome based on the framework, spanning across the grid from within the utility infrastructure and to the commercial and residential devices and applications supported by the Smart Grid, such that users and consumers enjoy a "plug and play" experience in their home energy management systems. The depth and robustness of such a "plug and play" experience is dependent on the capabilities of the underlying standard set being evaluated and essentially requires context specific processes in the framework to validate configuration requirements for the systems under test.

The framework must address test implementation and execution issues as well. These include qualification criteria for test laboratories and accrediting organizations, and recommended best practices to ensure that test results achieve their desired intent and are used in an appropriate and consistent manner. Suppliers, test labs, and certifying organizations must have a consistent approach in documenting test results such that readers of the results, whether test agencies, end users or other test program operators are reading and interpreting results as intended. The documentation must also be sufficient to ensure that the test can be repeated with comparable results by another test laboratory.

The framework must take into consideration the evolutionary progression of the Smart Grid, and be structured to allow maturation of existing technologies and introduction of emerging technologies. Additionally, the framework must accommodate versioning and backward compatibility. Finally, the framework must provide for a feedback mechanism to coordinate information exchange between test and certification entities with the standards setting organizations and authorities having jurisdiction to assure that observed field experience is acknowledged and addressed in progressing the baseline standards and test regimes supporting Smart Grid interoperability.

The framework should therefore include the following at a minimum:

- Qualification criteria for test laboratories and development of test reports
- Qualification criteria for issuing certification documents
- Example processes (Use Cases and Case Studies) and documentation associated with testing and certification activities which can mature over time and in concert with in-the-field deployments and technology evolution
- Example processes which can be used in providing feedback, including best practices, to the various industry recognized standards groups, vendors, legislators and regulators to improve standards and conformance documentation (test reports and certifications)
- Processes to address standards testability gaps and test capability issues which can be used to identify and communicate the need for additional working groups in support of interoperability standards development, testing and certification.
- Recommended practices to evaluate and assess the depth of testing requirements both for individual standards and for collections of standards that combine to address specific deployment issues.
- Recommended practices on test method and procedures documentation, as well as the use of test cases and test profiles where applicable in addressing interoperability issues
- Recommended practice for the development of testing and certification profiles based upon industry-developed use cases.
- Recommended practices on the validation of test plans and test cases to help assure alignment with the intent of standards and appropriate representation of expected usage in

deployment. This should also include processes on the use of standardized test references or test beds (e.g. “golden” reference models and test platforms).

- Where feasible and appropriate, these framework elements should be adopted and/or derived from existing international standards for conformance testing frameworks.

2.2 *Value Proposition*

The vision of an interoperable Smart Grid is dependent on the use of well defined and industry accepted standards, as well as appropriate mechanisms and controls to assure that the systems and devices comprising the Smart Grid conform to the identified standards, and further that their integration is equipped with the means to assure interoperability.

A comprehensive and robust testing and certification program, developed by trusted industry experts and adopted by all key stakeholder of Smart Grid interoperability will accelerate deployment ready solutions with a level of operational assurance meeting the expectations of both the industry and the public that will be the ultimate beneficiary of these technologies.

2.3 *Universe of Standards to Focus On*

The range of standards organizations and their Smart Grid related standards products are numerous. Standards pertinent to this effort may originate in formal, consensus-based standards development organizations (SDOs) or from membership-based alliances and consortia that focus on specific technology areas (referred to as standards setting organizations or SSOs in this document). Additionally, standards may be regionally oriented or international in focus.

NIST has identified and published a list of priority standards supporting Smart Grid implementation. The SGTCC will focus on that collection of standards as a starting point, as well as identifying supplemental standards where needed to address issues and gaps. Most likely, supplemental needs may require new work from standards setting organizations.

In addition to the cited technical standards, the testing and certification effort will require focus on the various national and international standards that provide criteria for quality testing practices, lab accreditation practices and related operational standards used in the testing and certification industry to help provide assurances of test lab competence and test program effectiveness. Commonly used criteria of this type are produced by the International Standards Organization (ISO).

As the body of potential standards is broad, effort will be needed to prioritize those to be addressed in early phases of the program, as well as to understand the interrelationship of standards where they combine to address specific domain issues. For example, interoperability of devices within the grid may be impacted by hardware and software related standards, which may not be consolidated within a single document, but requires the use of two or more standards to address specific usage scenarios. Additionally, the cited standards will need to be evaluated for test readiness, and their contribution not only from a conformance viewpoint, but their capability to help facilitate desired interoperability. Using the same device example above, conformance of a device to both a software standard and separate hardware standard may not assure interoperability where independent standards initiatives did not coordinate on the foreseeable implementation of their respective standards products.

2.4 *Steps to Ensure Consistency*

Consistency and repeatability are two key attributes of successful test and certification programs. These aspects can be considered on several levels, however for the purpose of developing a Smart Grid framework a focus should be made on consistency of approach between standards organizations and consistency between the test laboratories that execute programs based on cited standards. The end expectation is that a product tested to a specific standard will follow a consistent approach that will help assure repeatable results across test labs, as well as if tested multiple times in the same lab. Such a result establishes the required confidence in the efficacy of the standard and test processes.

Standards Organizations

Standards organizations each have their own defined practices and procedures in the life cycle of the standards that they develop. It should not be anticipated that Smart Grid interoperability efforts will alter long standing processes and procedures of individual standards setting organization used in the development of their standards. What can be affected in the standards development process, at least where Smart Grid issues are involved, is to advocate for and influence the mindset of the standards developers to recognize the role their standard will play and the need for the standard to provide clear direction on its use in needed post-publication testing and certification activities. A consistent approach to clearly expressing how the criteria are to be evaluated will not only accelerate Smart Grid interoperability, but will also enhance the value of the standard itself. Vague and undefined standards language with respect to testing and conformance will likely diminish value and interest in a standard where it remains open to interpretation and lacks the content necessary for consistent application.

Laboratories

While there are common laboratory practices supporting the quality and integrity of the services provided, it must be recognized that domains of expertise from one laboratory to the next can vary greatly. Consistency can be established first through an industry expectation of commitment to adhere to general best practices in the execution of test programs and generation of test results. A clear understanding and representation of the technology areas serviced by a laboratory will also be important to establishing consistency and quality. A communications technology oriented laboratory is expected to have personnel knowledgeable in that subject matter, and not purport to be experts in all Smart Grid areas, but to apply their expertise in the most mutually beneficial area. Personnel and test equipment quality processes will be a differentiator to help assure consistency.

Inter and Intra Lab Repeatability

Standards that clearly define criteria for conformance and interoperability, coupled with quality laboratory practices are expected to yield repeatable test results. A product tested to the same standard at different laboratories should generate the same results if consistent practices are employed.

Additionally, if multiple test trials are performed in a single lab for the same product, it is expected that repeatable results will ensue. Laboratories often perform in-house quality checks to assure repeatability, both for their own confidence as well as when called for in a standard or as part of a formal accreditation process. Some test industries also employ multi-lab "round-robin" testing where the same product is circulated among the participating laboratories for testing, and results are shared between labs so that their consistency and repeatability can be validated. Such round-robin testing can also be valuable in validating new standards and test processes to assure they provide clear definition and accomplish their intended goals.

2.5 *Comparable Programs*

Testing and certification of Smart Grid systems and devices is a very broad and complex undertaking, with minimal precedents for comparison. There are however numerous testing and certification programs across many industries and technology areas. These may be useful to investigate in evaluating and developing best practices for Smart Grid testing and certification. Programs exist for both market-driven initiatives, as well as regulatory-driven initiatives, with each type providing valuable insights for the development of a new program.

The task is akin to developing standards for the next-generation telecommunications network. This effort has spanned many years, continues to evolve, and involves dozens of standards development organizations. Also, like the telecom network, the Smart Grid is almost entirely owned and operated by industry. Therefore, Smart Grid interoperability and cyber security standards must reflect industry consensus, with active participation, and where required, leadership and coordination by government.

A vital issue to be addressed is positioning the value/need for conformity assessment within the development cycle of a specific standard. Existing standards have often not been developed with conformity/certification in mind, and thus require re-work or supplemental implementation documents to translate the standard into a conformity program if a need is identified after the fact. Conversely, where a certification need is identified in the absence of a standard, the opportunity exists to develop a standard with the required level of detail that allows a seamless transition from standard to certification program. While this second path may be more desirable, it can also be challenged by time to market issues, where the industry need may be sooner than practical for development of an industry consensus standard.

An additional factor to be addressed across various scenarios is industry "food chain" that drives the need for certification. Generally, conformity/certification is driven by the needs or perceived value to an end user. An end user however may take different forms. At one extreme, a consumer may value a particular product certification to assure safety of use, expected performance or some other parameter of importance. One step below, the manufacturer of that product may require certain certifications from their supplier of components where those may be critical to the conformance of the final assembled product. In turn, those sub-component suppliers may place conformance requirements on their suppliers of materials needed in building their component devices. Thus, certification programs can take place at a variety of levels on the path of product development as it progresses towards an ultimate end user.

Another factor in successful certification programs is the support (and preferably demand) from key end users/consumers of the devices being certified. A good example of this factor can be seen in the certification programs services used by many companies in the wireless communications industry, operated by the CTIA (International Association for the Wireless Telecommunication Industry). These programs draw from various standards, and are widely required and used within that industry. While different in principle from Smart Grid, some basic concepts do help to enable the interoperability in the seamless use of mobile devices on public networks. Their certification programs are successful for a few important reasons:

- Major wireless network operators (end users) require that wireless devices used in their network be certified within the applicable CTIA program. Because the operators typically offer devices for sale to their customers, this drives the device manufacturers, as partners to the network provider, to work together to assure their devices meet these specifications, thus maintaining their status as a preferred device manufacturer to the operator.
- The CTIA officers and board of directors are largely executive management and chief technical officers from most of the major wireless network providers and wireless device manufacturers. This group of individuals' collective decision that certification programs are important and of value to their companies becomes an executive mandate within each of their companies that certification is a required part of their daily business. As is the case for government regulated certifications (e.g. product safety), achieving certification is a business requirement and not subject to debate and acceptance at lower levels within these organizations.
- Device certification by an organization helps advocacy efforts with government entities by anticipating consumer expectations and concerns, and proactively developing programs that help assure their customers of reliable and safe product operation. This helps mitigate against consumer complaints/concerns leading to government mandated programs. Market and business driven initiatives are often more desirable than legally mandated programs in achieving a balance where industry is comfortable and confident in the program aligning with their business objectives and end user expectations.

2.5.1 *Cost Ratio Metrics*

Broad adoption and success of any test and certification program for Smart Grid systems and devices requires that the program be financially viable. Two key issues to consider in the structure of any new program are:

1. Is the cost of testing reasonable relative to product cost and volume of deployment
2. Is the cost of testing reasonable relative to the risk of product failure in the field

The first issue of test cost relative to product cost is a primary concern for manufacturers, with a secondary impact on the end customers for the product. A manufacturer must factor cost of testing, along with design, production and all other aspects required in delivering a final product. Manufacturers typically undertake some level of internal product testing and quality controls to assure performance expectations. In a number of industries, the manufacturer testing component is significant. While the relative cost of testing as compared to the overall cost of product creation can vary depending on the product, the testing cost is usually not a dominating contributor to the overall cost. Where test costs are high, the manufacturer retains the recourse of accommodating those costs through higher pricing for their product. Therein lays the secondary impact on end customers, as they will typically expect a high performance and quality product with a low cost.

The second test cost issue for consideration is that cost versus the costs associated with failure of deployed products. A worst case scenario for manufacturers, system users and consumers is a case where product performance and interoperability has been insufficiently verified prior to wide scale deployment. This leads to field repairs, replacement and customer dissatisfaction. The incremental cost of additional testing in the pre-deployment phase is most often a fraction of the cost associated with system wide failure mitigation.

Manufacturers and system users, in their natural desire to be cost conscious, are often inclined to curtail testing efforts to the minimum necessary to reach a degree of comfort with anticipated field performance. The majority of situations operate sufficiently with this approach, when non-critical technology issues or low cost corrections are involved. However in mission critical technology deployment, a category reasonably applied for the Smart Grid, there is a strong need to go above and beyond in testing conformance and interoperability to help assure performance, robustness and security expectations are comprehensively addressed, including those low probability events that may have significant impact on the grid.

A challenge in the development and implementation of Smart Grid testing and certification programs will be to define how comprehensive test programs should be, balancing performance, security, risk and cost to achieve an acceptable balance in which expectations are met, while striving to assure that implementation is not cost prohibitive to a point that impacts the support and engagement of key technology providers contributing to the effort.

3 Terms and Definitions

This section provides key definitions related to conformity assessment and acronyms used within this document. Many of the definitions are taken from *ISO/IEC 17000:2004: Conformity Assessment – Vocabulary and General Principles or other sources as indicated*.

3.1 Key Definitions

Accreditation - third-party **attestation** related to a **conformity assessment body** conveying formal demonstration of its competence to carry out specific conformity assessment tasks. (ISO/IEC 17000:2004)

Accreditation body - authoritative body that performs **accreditation** (ISO/IEC 17000:2004)

NOTE: The authority of an accreditation body is generally derived from government.

Architecture**:** The conceptual structure and overall organization of the Smart Grid from the point of view of its use or design. This includes technical and business designs, demonstrations, implementations, and standards that, together, convey a common understanding of the Smart Grid. The architecture embodies high-level principles and requirements that designs of Smart Grid applications and systems must satisfy. (NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0∗)

Attestation - issue of a statement, based on a decision following review, that fulfillment of specified **requirements** has been demonstrated. (ISO/IEC 17000:2004)

NOTE: the resulting statement, referred to in this International Standard as a “statement of conformity,” conveys the assurance that the specified requirements have been fulfilled. Such an assurance does not, of itself, afford contractual or other legal guarantees.

Certification - third-party **attestation** related to products, processes, systems or persons. (ISO/IEC 17000:2004)

NOTE 1 Certification of a management system is sometimes also called registration.

NOTE 2 Certification is applicable to all objects of conformity assessment except for **conformity assessment bodies** themselves, to which **accreditation** is applicable.

Conformance Testing - process of checking, via test assertions, whether an implementation faithfully implements the standard or profile.

Conformance Testing **-** International standard ISO/IEC 10641 defines conformance testing as a “test to evaluate the adherence or non-adherence of a candidate implementation to a standard.” In general, conformance testing validates that a single implementation adheres to the requirements of the specification. This type of testing is normally accomplished by executing an implementation against a conformance test engine.

NOTE: Most standards define sets of functionality that may be implemented from the standard with the resulting software designated as conformant. However, if two implementations that are certified as conformant include different subsets of functionality, achieving interoperability between these two implementations will be problematic depending on how well the standard specification handles such situations. Thus, it is usually necessary in interoperability and conformance testing to define a “profile”: a subset of the specification that all implementations must include if they wish to be interoperable.

Conformity Assessment - demonstration that **specified requirements** relating to a **product**, process, system, person or body are fulfilled (ISO/IEC 17000:2004)

NOTE 1: The subject field of conformity assessment includes activities defined elsewhere in this International Standard, such as **testing**, **inspection** and **certification**, as well as the **accreditation** of **conformity assessment bodies**. (ISO/IEC 17000:2004)

NOTE 2: The expression “object of conformity assessment” or “object” is used in this International Standard to encompass any particular material, product, installation, process, system, person or body to which conformity assessment is applied. A service is covered by the definition of a product (see Note 1 to 3.3). (ISO/IEC 17000:2004)

Conformity Assessment **-** Conformity assessment is defined in ISO/IEC Guide 2: 1996 as: "any activity concerned with determining directly or indirectly that relevant requirements are fulfilled." Conformity assessment procedures provide a means of ensuring that the products, services, or systems produced or operated have the required characteristics, and that these characteristics are consistent from product to product, service to service, or system to system.

Conformity assessment includes: sampling and testing; inspection; certification; management system assessment and registration; accreditation of the competence of those activities and recognition of an accreditation program's capability. A specific conformity assessment process may include one or more of these conformity assessment activities. While each of these activities is a distinct operation, they are closely interrelated. In addition, standards are interwoven into all aspects of these activities and can have a major impact on the outcome of a conformity assessment process.

Conformity assessment activities form a vital link between standards (which define necessary characteristics or requirements for products) and the products themselves. Together standards and conformity assessment activities impact almost every aspect of life in the United States. (NIST – Unknown)

Conformity assessment body - body that performs conformity assessment services

NOTE: An **accreditation body** is not a conformity assessment body. (ISO/IEC 17000:2004)

Framework – A basic conceptual structure used to solve a complex issue; set of processes, concepts and tools

Harmonization**:** The process of achieving technical equivalency and enabling interchangeability between different standards with overlapping functionality. Harmonization requires an architecture that documents key points of interoperability and associated interfaces. (NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0∗)

Inspection - examination of a product design, **product**, process or installation and determination of its conformity with specific requirements or, on the basis of professional judgment, with general requirements. (ISO/IEC 17000:2004)

NOTE: Inspection of a process may include inspection of persons, facilities, technology and methodology.

Interoperability Testing – "The capability of two or more networks, systems, devices, applications, or components to exchange information between them and to use the information so exchanged."[3]

In general, interoperability testing verifies that two or more implementations adhere to the standard (i.e., are conformant to) *as* they intercommunicate. An important point to note is that saying a single system or device is interoperable has no meaning unless one defines with what it interoperates. Interoperability denotes a relationship with other implementations; conformance only relates the standard the system, device or network implements but being conformant to the specification is a pre-requisite to interoperability.

Interoperability **-** The capability to communicate, execute programs, or transfer data among various functional units under specified conditions. (American National Standard Dictionary of Information Technology (ANSDIT))

Interchangeability**:** An extreme degree of interoperability characterized by a similarity sometimes termed "plug and play." Interchangeable components can be freely substituted without loss of function and requiring minimum to no additional configuration. (NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0∗)

Profiles - define conforming subsets or combinations of base standards used to provide specific functions. Profiles identify the use of particular options available in the base standards, and provide a basis for the development of uniform, internationally recognized, conformance tests. [ISO/IEC TR 10000-1:1998]

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[3] "EICTA Interoperability White Paper," European Industry Association, Information Systems Communication Technologies Consumer Electronics, 21 June 2004.

Reference Model: A set of views (diagrams) and descriptions that are the basis for discussing the characteristics, uses, behavior, interfaces, requirements, and standards of the Smart Grid. This model does not represent the final architecture of the Smart Grid; rather it is a tool for describing, discussing, and developing that architecture. (NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0∗)

***Requirement*:** 1) A condition or capability needed by a user to solve a problem or achieve an objective. 2) A condition or capability that must be met or possessed by a system or system (NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0∗)

Surveillance - systematic iteration of conformity assessment activities as a basis for maintaining the validity of the statement of conformity. (ISO/IEC 17000:2004)

Testing - determination of one or more characteristics of an object of conformity assessment, according to a **procedure.** (ISO/IEC 17000:2004)

NOTE “Testing” typically applies to materials, products or processes.

Test scripts – a set of instructions that will be performed on the system under test to test that the system functions as expected

Test harness – (sometimes referred to as an automated test framework in software testing) is a collection of software and test data configured to test a program unit by running it under varying conditions and monitoring its behavior and outputs.

Use Case – a description of a system’s behavior as it responds to a request that originates from outside of that system (captures behavioral requirements by detailing scenario driven thread through the functional requirements)

3.1.1 *Differences between Product Certification, Conformance testing, Compliance testing*

The terms conformance testing and compliance testing are loosely used across industry generally with the same intent and meaning. In both cases, the terms refer to testing a system or device against a defined set of criteria, and evaluating the test results against the metrics defined within the criteria. Conformance or compliance to the criteria implies a passing or successful result. The term conformance is more widely used and generally associated with testing programs that are of a voluntary or market driven nature. The term compliance is more closely associated with mandatory or regulatory oriented programs. It should be noted that these generalizations are not absolute, but a trend, and in most cases the terms are used interchangeably.

Product Certification is a more specific term, and typically an extension of conformance/compliance testing. In most cases, programs granting certification against a set of criteria require that the system under test meet those 100% of those criteria, or other specific definition of required results necessary towards the granting of certification. Certification can also be viewed as a “snapshot in time” – the product met all the criteria required for certification for the specific units tested and on a given date. Certification programs often add an element of ongoing surveillance or quality checks to give greater value to the certification and help assure end users that products remain certified.

3.2 *Acronyms*

ANSI	American National Standards Institute
CSWG	Cyber Security Working Group
DEWG	Domain Expert Working Group
EISA	Energy Independence and Security Act
FCC	Federal Communications Commission
FERC	Federal Energy Regulatory Commission
GWAC	GridWise Architecture Council
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
NIST	National Institute of Standards and Technology
SDO	Standards Development Organization
SGAC	Smart Grid Architecture Committee
SGIP	Smart Grid Interoperability Panel
SGTCC	Smart Grid Testing and Certification Committee
SSO	Standards Setting Organization

4 Actors – Roles and Responsibilities

Actors as used in this document are principle stakeholder organizations that will have a primary role in ensuring interoperability is achieved. The key actors and a description of their roles and responsibilities relative to Smart Grid testing and certification is provided in this section. Other actors are mentioned in various parts of this document; however those below should be considered the key organizations.

4.1 *Standards Organizations*

Testing, conformance and interoperability require standards and standardized test methods and processes to assure consistent and repeatable results. Standards organizations may be formal, consensus driven standards development organizations (SDOs). Alternatively, they may be alliances and consortia focused on specific technology areas (standards setting organizations). Regardless of the approach in the development of standards, conformance to a standard and interoperability testing require a clear definition of what conformance or interoperability means relative to a specific standard or test program. Standards organizations, or a designated testing authority, should be responsible for establishing these conformance criteria in the development process for the standard. These criteria should be based upon the projected use of products or services designed to meet the standard.

While many standards and organizations are effective in providing these clear definitions, many standards, including many on the NIST identified priority list, do not provide explicit conformance definitions and leave those determinations up to end users and test laboratories. Often, this approach is taken with good intentions to assure that innovation is not constrained, and the development of test programs is left to organizations outside of the standards setting body to implement.

Enabling the desired levels of Smart Grid system/device conformance, interoperability and certification will require active participation by standards developers. In the short term, they will be needed to facilitate clarification and interpretation of existing standards as those transition into testing programs.

In the long run, standards developers will need to be strongly encouraged to be cognizant that their standards efforts will lead to testing programs, and as such to incorporate the necessary information to allow a seamless transition from standard to conformance and interoperability testing.

4.2 *Hardware and Software Vendors*

Follow the standards, describe which they support, and to what level of compliance as appropriate.

Vendors of hardware and software systems, devices and solutions are a key actor within the Smart Grid ecosystem. The concept of a Smart Grid testing and certification program implies that those systems, devices and solutions will be subjected to testing and analysis as a condition of deployment by end users. As such, these vendors will need to proactively self-assess that they are designing and producing their products in accordance with the specified standards, and assure that they are positioned to succeed in meeting conformance expectations when testing gets underway.

Hardware and software vendors already perform internal testing and evaluation to assure their products perform as expected. Certification requirements and programs may necessitate that these vendors take a more rigorous approach in their internal assessments, to minimize the likelihood of non-conformances or other issues being identified when subjected to independent assessment.

These vendors will be an important contributor to the development and implementation of test and certification programs. They have the depth of their internal test experience and product performance knowledge in their areas of expertise to help assure that the test programs are robust and provide a level playing field across their own product lines as well as their competitors who will face the same test regimes.

The eager and voluntary participation of the vendors will also provide confidence to end users and regulators that the vendors are proactively working to assure interoperability. The alternative to a voluntary and collective approach is a regulatory mandated approach that may be less open to vendor input and more challenging for meeting expectations from a vendor point of view.

4.3 *Test Labs*

Test laboratories will have a major role in ensuring Smart Grid conformity and interoperability. The SGTCC will need to develop the required guidance for test lab responsibilities and expectations, as these labs will develop and implement test procedures for standard conformance and systems interoperability.

Test labs to be addressed include independent third party labs, as well as organization internal labs (sometimes referred to as first party labs). Certification programs predominantly have their testing performed by independent third party labs and use a variety of criteria in choosing labs appropriate to the particular area of test including:

- Laboratory technical capability
- Financial stability
- Adherence to laboratory quality standards
- Assurance of no conflict of interest concerns

The laboratory selection criteria will be established by program leadership of the specific organization providing the certifications. It is recommended that the practices and processes developed by the SGTCC be used in implementing the programs within the test labs.

The required laboratory technical capabilities and requirements should be established in advance by the selection team. This may include requesting information such as the lab's experience in a particular technology, available test equipment, qualification of testing staff, adequacy of laboratory space, and possibly geographic considerations and standards familiarity.

Financial stability is an additional selection criterion. The selection team must assure that the laboratory is a viable entity with sufficient business and capacity such that it is very likely to remain in business throughout the expected period of performance. It must also have any required financial capabilities to permit efficient contracting, billing and collections capacity, to meet the needs of the program, whether those interactions are between the lab and the program, or between the lab and individual companies testing within the program, depending on the preferred arrangements of a given program.

Laboratory quality systems should also be a selection criteria. At one extreme, some critical technology areas may desire that a laboratory achieve ISO 17025[4] compliance via a reputable laboratory accreditation entity. This will be a strong demonstration that the lab adheres to required equipment calibration processes, uses and controls test plans, adequately provides staff training and other important characteristics to assure quality services. Depending on the program needs, ISO 17025 can be achieved at a more general level or targeted to a specific testing service offering. Laboratories will generally not have achieved ISO 17025 to a newly launched program until it has been operational for some period, allowing the lab to put in place the required elements of its quality system specific to that program. As such, the selection criteria may choose to incorporate a requirement to achieve accreditation at a particular point in the future, but no less than six months from program initiation. The selection criteria must recognize that specifying a particular accreditation carries a cost to the laboratory that may influence the overall testing costs for program participants.

For other technology areas, accreditation to ISO 17025 may not be fully merited. While the spirit of the ISO 17025 criteria are typically embraced by most reputable test labs, some technology areas may carry lower risk, or market demand for a specific type of testing may be insufficient to justify the return on investment for the added costs to a laboratory capable of providing such services. The determination of the lab criteria appropriate to specific test scenarios is a topic that will require guidance from the SGTCC.

Finally, it must be assured that the laboratory does not have any conflicts of interest associated with the program or any of the participants in the program. For example, if a manufacturer has a financial stake in the laboratory or provides any management support (e.g. board of directors), then the lab may need to recuse itself from providing the required services to that company. There are many other potential conflicts that must be avoided. For these reasons, it will typically be preferable for a program to select at least two approved laboratories for the required services, to provide options in the event of conflicts, as well as to help assure competitiveness in the cost of services to program participants.

The SGTCC should pursue creation of a laboratory assessment checklist covering the aforementioned topics will be developed and used as a foundation for program reviews in the laboratory selection

[4] ***ISO/IEC 17025:2005*** – General requirements for the competence of testing and calibration laboratories

process. Some items contained in the checklist may not be applicable to specific programs, and likewise additional items may need to be added to the checklist on a program specific basis.

4.4 *Purchasers and Users of Smart Grid Products and Services*

Purchasers and users of Smart Grid products and services are an important actor in the process as they should be the entities that create the demand for conforming and certified products. As mentioned previously, vendors are always highly cost conscious and focus on optimizing their testing activities to gain the widest acceptance in a cost effective manner. Vendors may have some reservations about the added costs of formalized conformance and certification programs where none exist today. It will be incumbent on the product purchasers and users, whether commercial or consumer, to raise the bar on conformance expectations and create the demand driver that moves vendors toward these programs as a standard mode of operation.

Commercial end user Requests for Proposal (RFPs) should begin to include selected certifications and/or proof of standards conformance as a standard business practice, as those programs become available. Where certification is not yet offered, commercial end users can require test reports and other documentation to verify that standards conformance has been achieved, rather than relying on simple declarations made by the vendors. Such reports, upon review, can highlight the thoroughness and consistency of approach of the technical analyses behind conformance statements (or lack thereof) and help assure competitive vendor claims are comparable. This approach is commonly used in the telecommunications industry and has helped pave the way for rigorous and well-documented test programs that support systems interoperability.

Consumer end users also play a role in Smart Grid product selection as they become educated about certification of devices that they handle directly. Similar to consumer expectations raised through programs such as UL safety listings, WiFi enabled devices, EnergyStar rated products and the like, consumers can raise the bar on vendor devices to help assure interoperability at the level where there is direct daily interaction by the public.

4.5 *Federal, State, and Local Government and Regulatory Agencies and Legislatures*

Regulatory and governmental agencies are an important actor in the process on several levels. Clearly, much of the current standards and development of a national Smart Grid program is strongly supported and funded by government agencies.

As mentioned, vendors and end users have the opportunity to work collaboratively to develop programs and proactively participate in the testing, conformance and certification process to put in place a market driven system that sets and meets the expectations necessary to achieve interoperability. In the absence of such market cooperation, regulatory organizations retain the option of stepping in and creating legally mandated conformance and certification programs. Usually market driven programs are more desirable from the perspective of the vendor community.

While market-driven programs are desirable, there are a number of standards and use cases for Smart Grid where regulatory interest is likely. At the consumer level, technology issues associated with personal and public safety may best be served using programs such as those in practice today for consumer devices (e.g. OSHA, FCC). Similarly, selected security issues may preferably be managed with a degree of regulatory oversight. The SGTCC should consider these aspects in its work, recognizing that final determination of the authority for a given standard or technology may be determined by government policy or regulation.

5 High Level Work Flow and Framework Artifacts

This section describes key steps that the SGIP TCC should undertake to develop the final framework for smart grid conformance and interoperability testing. The guidelines described here are presented within the context of the architectural templates being developed in the Smart Grid Architecture Committee and the security guidelines being developed in the Cyber Security Working Group. The work of these groups provides a backdrop and foundation for the conformance and interoperability testing framework. The SGAC reference model and template architectures help segment the problem and identify key interfaces that scope testing for particular sets of standards and intra-standards testing whereas the guidelines of CSWG provide key constraints on how security considerations should be evaluated in testing.

The overall work flow of the TCC should address the following elements:

- Prioritized set of standards to develop guidelines for initially
- The level of depth and types of testing required for each
- Best common practices across all standards
- Specific artifacts necessary for a framework
- Comparable Initiatives
- High level work flow description

5.1 ***Prioritized Standards List***

The NIST roadmap identified a set of standards that are of particular importance to early smart grid deployments to ensure that public funds do not result in stranded assets due to the inability of them to interoperate as additional and new technologies and products are deployed. It is therefore appropriate to focus the conformance and interoperability framework development effort on those standards initially. Some of the applicable standards are more mature than others and should be prioritized accordingly.

The process by which standards prioritization is performed is an important challenge for the SGTCC. There are a number of different characteristics and influences within the set of standards cited in the NIST roadmap that must be considered and balanced in setting priorities. Some of these factors include:

- A standard's readiness for testing
- Single standard versus intra-standard solutions
- Critical issue resolution versus complexity

<u>Standard Test Readiness</u>

A fundamental issue that must be addressed by the SGTCC is the readiness of a standard to transition into testing and certification programs. There is a wide spectrum of test readiness across all technology standards, and the same can be said for those cited in the NIST roadmap. At one end of the spectrum are standards that have been developed to place basic boundary conditions on a technology to provide a focused industry approach, but stop short of being so specific as to potentially inhibit innovation. These standards can appear somewhat abstract and implementation of the standard in product design, not to mention associated standards conformance is left to engineering judgment of the user.

The other end of the test readiness spectrum are those standards in which their developers set out early in the standardization process to parallel requirements with specific methods by which conformance to those requirements could be verified. Often, emerging technologies take a more broad initial approach leaving room for evolution, whereas standards created by consortia/alliances may be more specific as those organizations often have a testing and certification element in their organizational plan.

Between these two extremes are standards which appear to contain the necessary technical detail but fail to mandate key features of the standard. This overuse of optional features results in a standard with clear conformance conditions but are unlikely to possess characteristics amenable to interoperability testing.

The SGTCC must address a recommended approach to implement testing programs where they are clearly defined, an approach to advocating for new work by standards setting organizations where test specifications are viewed as insufficient, and a means to assessing the effectiveness of these testing specifications in practice.

<u>Single Standard versus Intra-Standard Solutions</u>

It will be important for the SGTCC to receive and understand architectural recommendations generated by the SGAC enabling test recommendations to align with the various domains and interfaces addressed in the overall architecture. Further, the SGAC should be able to provide the SGTCC with their views on critical deployment issues and needs to support their vision. This will help support the SGTCC in assessing where test and certification programs for specific standards may be effective and where there is a clear need to develop a multi-standard or intra-standard test program to assure interoperability for specific scenarios.

This consideration is further compounded when overlaying security concerns atop the architectural structures. Many technology specific standards do not explicitly provide coverage for security issues in addition to the key functionality and performance requirements specified in the standard. While security is recognized as important, some standards may leave those considerations to companion criteria or rely on cross-reference to security focused standards. This further drives the likelihood that test and certification programs may more frequently need to be structured as multi-standard efforts.

The SGTCC will need to develop clear approaches to use case evaluation as a tool for prioritization. Considering use cases and potential scenarios will provide a top down and more practical aspect to determining the standards that are key elements enabling interoperability, and most likely resulting in multi-standard test cases.

Critical Issue Resolution versus Complexity

Developing an understanding of the high risk (weak link) points in the end to end solution will help drive the areas of prioritization. The SGTCC must engender willingness within industry to fully address these potentially complex testing scenarios, and mitigate against simplistic solutions that only partially address critical issues and leave potential for unaddressed problems. Essentially a balance needs to be achieved in which a comprehensive test program provides strong assurance of interoperability, while recognizing that the program must be achievable in a reasonable time frame and cost effective relative to the potential consequences on an interoperability failure.

5.2 *Level of Testing Required*

The nature of some standards, their scope of influence, existing testing guidelines, user groups, published test procedures, etc. is such that some standards may not require the same depth of treatment as others. The TCC framework should clearly identify guidelines for recommended approaches to determine the level of testing required.

It is important to understand the specific elements within individual standards that will be most critical in enabling interoperability. Ideally, full conformance to an individual standard may be desirable, however interoperability may be impacted only be specific elements within that standard. An approach to establishing levels of testing may be advantageous in expediting selected programs. A basic level would be to assure all critical interoperability related parameters within a standard are met as minimum criteria. A more advanced and comprehensive conformance across the full standard might act as a second level that is preferred, but not within the critical path of establishing interoperability. It should be noted that not all standards and technology areas may readily lend themselves to be parsed into levels, however this consideration should be addressed in the prioritization process.

Further, where levels of testing are practical, guidance will be needed on the responsible parties that make such a determination and that select the specific criteria sets associated with each level. These determinations will likely be outside the domain expertise of the SGTCC, however guidance will be required in establishing the responsible parties. Where multiple standards are involved in a use case driven program that encompasses levels, setting guidelines for the interaction among multiple domain expert groups representing the various standards areas will also be important.

5.3 *Best Common Practices across All Standards*

Once the priority standards and levels of testing are determined via processes developed by the SGTCC, a next step for the SGTCC will be to develop recommended practices that include metrics to assess the efficacy of the test and certification programs. Various metrics and processes can be adopted, with the items addressed in this section being generally applicable across the range of standards being considered.

The final framework should identify practices that are common across all standards and standard types. This includes test case availability, test case validation and thoroughness of testing, applicable metrics to assess that test processes are sufficient for the product life cycle, processes to identify gaps in the testing process, evaluation of interoperability needs beyond basic standards conformance, steps necessary to ensure that multiple parties testing to the same framework get consistent results and recommendations on how to address inter-standard issues at boundaries.

5.3.1 *Open and Published Test Cases*

Standards must have associated test procedures or test cases in order to be effective for use in a testing and certification program. As previously mentioned, a challenge to be addressed in the final framework is that a number of the cited standards relating to Smart Grid may have insufficient detail to easily implement a consistent and repeatable test program. This is not uncommon as some standards are developed with a general approach, allowing latitude for innovation, however this flexibility can leave too much to interpretation in assessing conformance and interoperability.

Test procedures, detailed methodologies and specific test cases will be necessary to rapidly and effectively introduce test programs that help assure conformance and interoperability for the Smart Grid. Ideally, these testing elements will be directly documented and detailed in an existing standard or moving towards inclusion in upcoming revisions to existing standards. Where these details are embedded in a standard, they can be considered as openly available to the users of the standard.

Recognizing again that some standards do not include the necessary testing detail, a number of formalized testing programs have been created by industry groups and consortia in which the group membership has developed detailed test plan and test cases based on a specific standard or collection of related standards addressing a technology area. These are generally developed to operate a test and certification program that brings value to the group members both in assuring common testing and analysis for comparative purposes, as well as creating performance confidence for end users of the products and technology supported by the group.

Industry group or consortia test plans and test cases may or may not be published and openly available to all interested parties. Sometimes these test plans and test cases are only available to members of the industry group (and membership fees can range from relatively low to tens of thousands of dollars). Additionally, in some cases, independent laboratories are contracted by an industry group and they develop test plans, and these may be considered proprietary or intellectual property of the developing laboratory (possibly licensed to the industry group for use). The SGTCC must evaluate the open availability of test documentation across various standards and industry groups and recommend a plan that addresses the open availability of test plans and test cases, while recognizing that the business models for existing programs and labs may or may not view open availability as desirable to their interests.

The SGTCC should recommend that each standard has a lead test authority. This organization may take inputs from other organizations, but the concept of a central clearing house must be maintained. This mandates that only one set of conformance and interoperability test cases applies to each standard.

5.3.2 *Validation and Thoroughness of Test Cases*

It will be essential to validate the completeness and effectiveness of testing programs established for individual standards and multi-standard, use case driven issues. Engaging the necessary expertise across stakeholder categories will help in assuring program completeness. It will also be critical to establish feedback loops and iterative improvements to the test programs as knowledge is gained through early stage test execution within programs.

Where standards or industry group specific documentation define test plans and test cases, there must be assurances that the proscribed processes are aligned with the intent of the standard, and will be repeatable in their execution and output when applied by different laboratories, across different products and systems. Development of test plans and test cases must not be performed as a paper exercise, without ongoing lab evaluation and validation during the development process. Identifying gaps, problems and inconsistencies in test plans and cases after publication erodes confidence and may lead to repeat testing of devices evaluated prior to identification of the issue, depending on the significance and impact of the issue.

It is to be expected that technology evolution for both the products under test and laboratory test equipment, as well as evolution in field architecture and practices, will likely necessitate revisions to test plans and test cases over time. Evaluation of test plan and test case changes should be viewed as an ongoing process including validation that test modifications meet the desired intent, and allow compatibility with the processes and products evaluated in the past.

5.3.3 *Life Cycle Metrics*

Processes will need to be in place to assess standards, use cases and associated test processes as technology and the Smart Grid evolve. It should be anticipated that products will change and improve over time providing new features and performance capabilities. Test programs cannot remain static and will need to similarly progress to address these variants. Similarly, key learnings from the test programs and the advance of technology must also feedback into the base standards that the testing and certification is based upon. Without processes to update the standards accordingly, risk can be introduced where “non-standard” implementations and test processes arise to address deficiencies in standards.

5.3.4 *Gap Identification*

It should be anticipated that gaps will be identified in the cited priority standards and early phase test programs. Current standards were typically not constructed envisioning that they would become the basis for formal test and certification programs. Gaps may take the form of deployment scenarios not addressed by the standards developers, or where a scenario has been addressed, incomplete or vague language may require interpretation in translating the standard into a testing process. Additionally, some of these gaps may not be apparent at the outset of testing programs, but identified once test programs become more broadly implemented. Processes will need to be recommended that address identified gaps, through issue tracking and corrective action procedures, and cooperative engagement between standards development organizations and testing organizations.

5.3.5 *Conformance versus Interoperability*

Aside from the definitions provided earlier in this document, a practical matter of standards is that conformance to a specific standard, does not in and of itself assure interoperability of devices and systems when complex systems are constructed. Certainly, conformance to a standard is an essential building block on the road to interoperability, however additional measures may be needed to assure end to end interoperability. Hardware focused standards versus software oriented standards may often be developed by independent organizations with minimal coordination, yet in systems as complex as the Smart Grid, additional collaboration may be required to assure that these individual elements within the grid not only conform to their respective standards, but will also co-exist and interoperate as needed.

The SGTCC must consider this aspect in its prioritization process to assure that programs are addressing the bigger picture of interoperability and not acting as a simple check list of achieved conformance. Additionally, it will be important to identify needs and gaps across the cited standards where supplemental materials are needed to bridge standards conformance to broader interoperability.

5.3.6 *Results Consistency*

It is critical that test results be consistent when executing an agreed upon test program, regardless of the laboratory performing the testing. Early phase test programs may wish to consider recommended practices for inter-lab cooperation in sharing and comparing test results. Verification of test result consistency, clear and consistent understanding of the standardized test plans, and open dialogue on identified anomalies in the testing process will promote a rapid resolution to issues leading to the consistency necessary to provide interoperability assurances. Additionally, results consistency can be greatly aided by the use of standardized and agreed upon reference test tools, sometimes referred to as “golden” test tools, test beds, etc. The following section provides more detailed consideration of how such reference tools can help achieve results consistency.

5.3.6.1 “Golden” Test Tools

A common practice used in test programs across a wide range of technologies and standards uses reference test tools, both hardware and software, to provide a consistent and replicable approach in generating test results. A number of terms and variants are used in commonly describing these test tools such as “common test harness”, “golden reference test equipment”, and “golden reference test products”. Generally, these each represent test tools available to a test lab or end user to provide a consistent baseline test either as a standalone implementation or in concert with the many other types of test tools available.

A “common test harness” is essentially an automated software based test tool that is designed to test a particular system under sets of specified conditions. Using such a tool, comparative results can be generated in which the tool provides the consistency and the affects of changes in the system under test can be evaluated. Golden reference test equipment often refers to test tools that be configured in a laboratory to provide a constant ("reference") such that there is assurance that changes to the products comprising a system under test or configuration variants are consistently tested in the same manner, again allowing comparative results generation against a known standard. In some instances, a test product can be used as the reference sample to be used as a comparison point in laboratory testing.

The key point in the above paragraph is that successful testing programs assure that there is a known reference or constant to which the system is evaluated against the desired metrics to determine conformance. Successful test and certification programs that are performed across multiple test facilities implement processes to assure they are each measuring against a common known reference to achieve repeatable results regardless of location. Without this approach, laboratories would trend towards customized and independently designed test beds, with no assurance that results are comparative as there would be natural variation introduced through the custom designs.

5.3.7 *Inter-Standard Boundaries and Technology Specific Issues*

The SGTCC will need to address inter-standard boundary issues, particularly where use cases identify specific interoperability issues crossing not only system boundaries, but where those boundaries overlap with respect to the key standards defining either side of the boundary. Where domains cross, there is a good probability that standards may have been developed by different organizations, and collaboration between standards developers to help assure compatibility across those standards may range from being well coordinated to completely uncoordinated.

The TCC Framework should also seek to identify commonalities found within technology categories of standards that should be captured as best practices. The list of standards cited by NIST as priorities cover a wide range of technology areas across power engineering , communications systems, data structure and consumer products to name a few. Based on the technology area of the standard and the products subject to the standard, there will likely be common practices specific to the selected technology areas.

For example, testing of standards relevant to the electric interface of power system apparatus will have common requirements for simulating the interconnection with the electrical infrastructure during a test. Similarly, standards addressing wired communications might have a separate set of best practices as would standards focused on information models. Each of these standards categories will have their own set of best practices that can be identified.

The current testing and certification market tends to focus on single element or technology issues. For example, there are various programs that individually address specific wireless communications technologies, but few formal programs analyzing the interaction and interoperability across those alternative approaches – occasional test events or "plug fests" may be held as a venue to bring technologists across those areas together, but those are often more informal and development focused. Similarly, the various power technology and data structure standards testing efforts tend to focus on specific aspects within their respective domains.

Broader testing programs across technologies and domains tend to occur most often within end user lab and field trials, as well as in academic or government test beds. These programs may be proprietary in the case of end user internal evaluations, or research focused in the case of academia and government. Until now with the drive for an interoperable Smart Grid, these broad spectrum efforts have rarely been implemented with an aim toward independently determined conformance/interoperability leading to a certification that can be adopted by industry.

5.4 *Test Program Effectiveness*

Once test programs are underway and conforming/certified products begin to find their way to end users and field deployments, there is a need to consistently gather information on the performance and success of those deployments, particularly to gain information on problems, issues and identified opportunities for improvement of the test programs based on real world experiences

A process should be enacted to maintain a standing committee to identify field deployments with end users willing to proactively assess the utility of the test programs and provide input back to the committee. The committee should enable practices where this first hand information and experience can be provided as input to test program developers and certifiers, as well as standard developers to establish the feedback mechanisms that will drive constant process improvement.

5.5 *Specific Artifacts Necessary for a Framework*

This section describes the key elements of a framework. In essence, these elements are the types of rules that each actor will be recommended to follow. Most of the rationale for these artifacts has been presented in prior sections of this report.

1. Testing architecture

   Smart Grid architecture recommendations will be generated through the SGAC. A testing architecture corresponding with SGAC (and CSWG) guidelines will require close interaction among these related committees. The architecture should consider specific technical issues and standards proposed for certification, existing or needed test organization support, and recommended processes to establish and operate certification programs.

2. Thoroughness of testing

   A process document is needed to include recommendations on engaging industry experts to provide technical expertise for specific certification programs identified, to assure completeness and processes to establish feedback loops and iterative improvements to the test programs as knowledge is developed during program operation. While interoperability between critical standards might require a “plug-and-play” level of testing, less critical standards make accept a more interactive definition of interoperability. The SGTCC should provide a process to gauge the required level of interoperability testing and provide testing and certification profiles.

3. Assurance that test processes are sufficient

A process document is needed to assess standards, use cases and associated test processes as technology and the Smart Grid evolve. Processes should address technology and product evolution, as well as test program learnings in recommending steps to evolve test programs and standards to meet the evolving market

4. Testing Gap Mitigation

A process document is needed to address testing gap identification and mitigation. Processes should be recommended that address identified gaps, through issue tracking and corrective action procedures, and cooperative engagement between standards development organizations and testing organizations.

5. Lab Qualification

Test laboratory recommendations are needed to support the expected qualification and selection process in organizing the necessary test support for conformance and certification program. Basing recommended qualifications on existing standards and accreditation schemes is a preferred approach as these may be most expeditious for labs, in simply expanding their existing qualification into areas of identified need for Smart Grid. However, as noted earlier, a less rigorous approach may be necessary when low risk or market economies dictate only meeting the spirit of recognized accreditation schemes. The creation of a laboratory assessment checklist will be required to gauge the minimum laboratory qualification requirements.

6. Inter-standard Issues

Recommendations should be developed to promote cooperation and collaboration between standards organizations to address the testing and certification needs and criteria for technical scenarios in which integration of multiple standards impact on enabling interoperability.

7. Best Practices

It is recommended that guidelines be compiled for the operation of certification bodies and/or laboratories in their execution of conformance and certification programs. These guidelines should be based on existing certification industry practices after evaluation of successful processes that can be replicated for Smart Grid efforts.

8. Product Testing Guide

A product testing guide can be developed through the SGIP detailing how specific standards are to be applied for specific environments, and the specific tests applicable for the situation

9. Purchasers and Users Guide

The SGIP should develop materials to provide guidance to purchasers and end users of smart grid products. This document must provide a clear indication of available test programs for each Smart Grid use case and application. A simple matrix/checklist format would be the most beneficial form of such a guide, especially when purchasers or end users are developing RFPs.

5.5.1 *Example Approach*

Many of the issues and concepts discussed in this document can be put into context with the following examples. The first example considers the framework from a single standard view. The second takes the approach from an issue impacted by multiple standards.

For the first example consider a system in which data must be transferred across multiple points to support demand response. Most likely, a protocol will have been chosen based on industry practice coupled with guidance developed by the SGIP architecture committee. This protocol will likely be defined in a specific standard. From a testing and certification point of view, the following steps must be addressed:

- Is the standard for the protocol appropriate for this application?
- Does the standard define a method or process to assess conformance to the standard?
    - Is there a process by which testing organizations interact with the standards organization to share key learnings from implementation to provide continuous improvement and evolution of the standard to meet industry needs?
- Are there existing industry programs or practices used to verify conformance to the standard?
    - If yes, what processes do they have in place to certify to a standard and assure ongoing consistency in their issued certifications?
- Are there independent labs or organizations with test capabilities for the standard?
    - If yes, what qualifications does the organization have to instill confidence in their capabilities to perform testing to this standard?
- If industry programs or independent labs are not in place, what are the appropriate steps to be taken to put in place necessary assurance of standards conformance?
- Does conformance to the standard assure interoperability? If not, what additional processes are needed above and beyond those defined in the standard?

A second example is one in which multiple standards impact a deployment scenario. Consider a specific device within the grid, such as a smart meter. The questions raised for the first example should all be addressed in this scenario as well. Additional questions to be addressed include:

- What is the package of standards that are needed to address the operation of this device?
- Are there independent standards impacting the device from the perspective of hardware, software, security, regulatory/safety issues, etc.?

    - If so, are these multiple standards compatible or cross-referenced, or were they developed without interaction with each other?

- How do these standards interrelate in enabling and verifying interoperability of the device within the grid?
    - Are additional steps necessary to integrate these standards into a holistic test program that addresses the device in the context of its installed condition?
    - Are there programs or organizations in place that address conformance/interoperability of the installed condition?
    - Do end users perform in-house or field testing of the device when integrated into the grid?
    - Are there independent labs that are capable of testing the integrated deployment scenario?

For each of these types of examples, there are many more questions that will likely need to be answered with some variations depending on the specific systems and technologies under consideration. The Smart Grid testing and certification framework must develop the artifacts cited earlier in this document, as well as identifying and developing additional artifacts as needed to provide the necessary guidance and processes to enable the solutions that will support Smart Grid interoperability.

5.6 *Comparable Initiatives*

There are few examples of transformational industry initiatives as encompassing as the vision for an interoperable Smart Grid. Many wide scale networking technology introductions evolved opportunistically through innovations, without necessarily being a pre-meditated wide scale change to existing practices. Frequent references are made between the development of the Smart Grid as compared to the growth of the internet – while similar in concept, much of the initial development of the internet grew naturally from academic and government lab programs, without an overall grand vision of where it would evolve to over time. From a testing and certification perspective, the internet does not provide a good example as it did not have a broadly applied conformity element in its earliest formation.

One example of a pre-planned network transformation is the evolution in the past decade of major carrier networks as they move away from traditional circuit switched networks to IP networks, and in parallel transform their infrastructure from copper based networks to fiber optic networks. While vision of these transformations have been implemented with some variations between major carriers, all have been engaged in the use of standards and testing programs to enable this transformation. The collective vision has also considered the need to proceed through this evolution without disruption to customers and designing to enable future incorporations of evolving technology breakthroughs.

Verizon Communications designed and deployed a fiber optic network to provide the next-generation in communications for its customer base. Some similarities to Smart Grid initiatives were the need to install this new infrastructure without disruption to communications over existing networks, seamless transition for customers from the legacy network to the new network, their design for an evolving infrastructure to accommodate technology improvements, and extensive conformance and interoperability testing programs to assure robust and reliable performance. The network design was based largely on existing standards with gaps addressed through the development of new specifications to meet deployment needs. Other major carriers such as AT&T have also undergone similar network transformations.

5.7 *Overall TCC Work Flow for a New Standard*

This section describes an example workflow for a new standard. The SGTCC testing and certification program work flow facilitates an understanding of the roles and responsibilities for all SGIP organizations and stakeholders in the conformance and interoperability testing process.

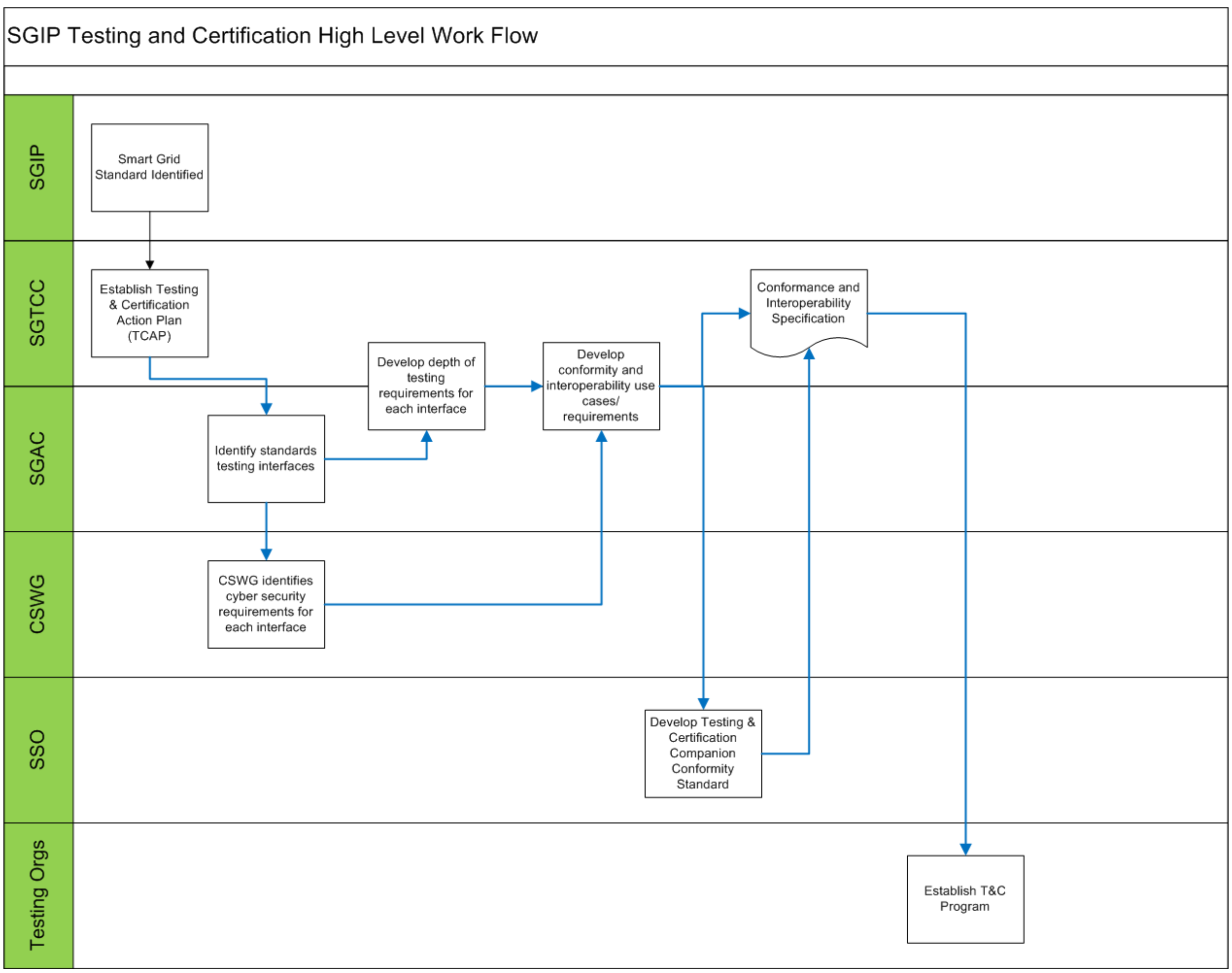

Figure 1 – High Level Testing and Certification Workflow

Figure 1, above, shows the business process model (BPM) or swim-lane model for the SGIP's testing and certification framework. The figure includes swim lanes that depict the responsible party for each step in the process. Each box within the BPM represents a step, task, or set of tasks which need to be completed. If a box within the BPM overlaps multiple swim-lanes, it means that there is dual responsibility for completion of that task.

The following information describes the steps involved in establishing a testing and certification program for a new SGIP-identified standard.

1. <u>Smart Grid Standard Identified</u> – the SGIP PAP teams use the PAP Project Lifecycle and the PAP Project Timeline and Milestones processes to execute their work in a streamlined fashion. The ultimate goal of each PAP is to move the PAP-relevant Smart Grid standards into a "SGIP-identified" catalog. The standard does not need to have completed the PAP process before the SGTCC moves to the next step and establishes a companion T&C project to accompany that standard.
2. <u>Establish Testing and Certification Action Plan (TCAP)</u> – When the SGIP has created the PAP and identified the standards setting organization (SSO) to create the standard, the SGTCC can begin developing its testing and certification program for that standard. The TCAP is an SGIP project that manages its activities similar to the PAPs. It has a standard project lifecycle, timeline and milestones, which will be developed with help from the PMO at a later date. However, the overall flow of each TCAP is exactly what is described in the steps that follow. Where regulatory interest is known or anticipated, additional coordination steps will be included in the TCAP development.
3. <u>Identify Standards Testing Interfaces</u> – the first effort within the TCAP is to identify all the relevant architectural interfaces the SGIP-identified standard touches. The SGAC evaluates the companion PAP and determines the domain and actor-to-actor interfaces. This information is published as a report to the SGTCC and the CSWG to assist them in developing their requirements for the testing and certification program.
4. <u>CSWG Identifies Cyber Security Requirements for Each Interface</u> – the CSWG uses the published report from the SGAC to identify their recommendations for cyber security requirements for each identified domain and actor-to-actor interface.
5. <u>Develop Depth of Testing Requirements for Each Interface</u> – the SGTCC will review the input from the SGAC and CSWG to determine what depth of testing is required for each architectural interface. The depth of testing should rely on standard architectural models, such as the GWAC stack, and provide details for which levels of the stack require testing.
6. <u>Develop Conformity and Interoperability Use Cases and Requirements</u> – the SGTCC uses the standard use case methodology to expose the testing and certification requirements necessary for each standard. The Use Case template can be found on the Interoperability Knowledge Base (IKB). The use of this methodology ensures that requirements are traceable and meet some functional business need or non-functional performance or regulatory need.
7. <u>Develop Testing and Certification Companion Standard</u> – in some cases a testing and certification companion standard will be needed (or already exist) that describes the testing requirements and procedures for the SGIP-identified standard. This document would be developed and provided by the SSO that developed the standard or another SSO that can support the development of a testing standard.
8. <u>Conformance and Interoperability Specification</u> – the SGTCC uses the use cases and requirements to create a standards testing and certification specification that fully tests the actor-to-actor interfaces identified by the SGAC. This includes both conformance and

interoperability testing. This specification provides the roadmap for the testing and certification communities to create their test programs.

9. Establish Testing and Certification Program – once the SSO's testing and certification companion standard and/or the SGTCC's conformance and interoperability specification have been published, the testing and certification stakeholder community can create programs for testing each SGIP-identified standard.

6 Conclusion

Testing and certification activities for smart grid devices and systems are an essential element necessary to assure smart grid interoperability. Conformance and interoperability assessments rely on standards and standardized test methods and processes to assure consistent application and repeatability of testing programs used for verification.

This document has described the many challenges and issues to be considered and addressed in building comprehensive testing and certification programs that will enable Smart Grid interoperability. It is important to recognize that there is not a one size fits all solution to addressing the myriad of technology issues in demonstrating standards conformance and interoperability. However, wherever possible, developers of these programs should follow the best practices cited in this document and strive to take a consistent approach in program development to best assure that programs meet and exceed the performance and quality expectations of all stakeholders.

7 References

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